2022 Report of the Section on *Ecology of Harmful Algal Blooms in the North Pacific*

The Section on *Ecology of Harmful Algal Blooms in the North Pacific* (S-HAB) meets once each year before the PICES Annual Meeting. Prior to the COVID-19 pandemic these one-day meetings were held in-person at the PICES Annual Meeting venue on the weekend before formal opening of Annual Meeting. Since 2020, these meetings have been held on-line weeks before the PICES meeting in a severely shortened format (2 h), greatly restricting interactions and progress. All S-HAB members look forward to 2023 when in-person meetings can again be held.

AGENDA ITEM 1

Welcome and Introduction

S-HAB met under the co-chairmanship of Dr. Mark Wells (USA) and Dr. Pengbin Wang (China) on September 14 at 17:00 (Pacific Daylight Time), September 15, 8:00 (Beijing), 9:00 (Tokyo/Seoul), and 10:00 (Vladivostok), 2020, via Zoom. The meeting began with welcoming comments from both Co-Chairs, and as new members/participants were present, was followed with short introductions by each participating member. Members from five PICES member countries were in attendance (*S-HAB Endnote 1*). The provisional agenda, shared among participants ahead of the meeting, was reviewed and was approved by the Section (*S-HAB Endnote 2*).

S-HAB participants attending the 2022 PICES Annual Meeting. First row, from left: Moonho Son, Pengbin Wang, Douding Lu, Mark L. Wells, Seung Ho Baek; Second row, from left: Yoichi Miyake, Mitsunori Iwataki, Yoshida Takafumi, Vera Trainer, Setsuko Sakamoto, Misty Peacock; Third row, from left: William Cochlan, Charles Trick, Ruoyu Guo, Chunlei Gao, Tatiana Morozova; Fourth row, from left: Chunjiang Guan, Minji Lee

AGENDA ITEM 2

HAB country reports

2.1 Canada (Reported by Andrea Locke and Andrew Ross)

2.1.1 New peer-reviewed publications and conference presentations

Publications

Boivin-Rioux A, Starr M, Chassé J, Scarratt M, Perrie W, Long Z, Lavoie D. Harmful algae and climate change on the Canadian East Coast: Exploring occurrence predictions of *Dinophysis acuminata, D. norvegica, and Pseudo-nitzschia seriata. Harmful Algae.* 2022 Feb 1;112:102183.

- Based on 24 years of monitoring data, a model was developed for *Dinophysis acuminata*, *D. norvegica*, and *Pseudo-nitzschia seriata*. All three species are predicted to shift their spatiotemporal occurrences during the 21st century.

Emam M, Caballero-Solares A, Xue X, Umasuthan N, Milligan B, Taylor RG, Balder R, Rise ML. Gill and liver transcript expression changes associated with gill damage in Atlantic salmon (*Salmo salar*). *Frontiers in Immunology.* 2022;13.

- Following exposure to harmful algal blooms, gill and liver samples from farmed salmon were analyzed for biomarker genes associated with tissue damage. Up- and down-regulation of specific biomarkers (*e.g.*, wound healing, stress-response, apoptosis, blood coagulation, transcription regulation) was observed, and was generally correlated with tissues damage.

Esenkulova S, Neville C, DiCicco E, Pearsall I. Indications that algal blooms may affect wild salmon in a similar way as farmed salmon. *Harmful Algae*. 2022 Oct 1;118:102310.

- Based on a limited number of wild juvenile salmon samples, analyzed following exposure to harmful algal blooms, histopathological evidence (gill damage, liver apoptosis) was found, indicating that HABs may directly affect wild salmon.

Esenkulova S, Suchy KD, Pawlowicz R, Costa M, Pearsall IA. Harmful algae and oceanographic conditions in the Strait of Georgia, Canada based on citizen science monitoring. *Frontiers in Marine Science.* 2021:1193.

- Based on thousands of samples collected in the Salish Sea, spatio-temporal patterns of occurrence for several harmful algae species were revealed, along with environmental drivers. Years with high levels of harmful algae were associated with negative impacts on shellfish and salmon aquaculture.

McIntyre L, Miller A, Kosatsky T. Changing trends in paralytic shellfish poisonings reflect increasing sea surface temperatures and practices of Indigenous and recreational harvesters in British Columbia, Canada. *Marine Drugs.* 2021 Oct 14;19(10):568.

- PSP poisoning frequencies increased over 62 years in British Columbia, Canada coinciding with rising global temperatures. Ongoing collection of data on harmful algae, especially in remote indigenous communities, is recommended.

McKenzie CH, Bates SS, Martin JL, Haigh N, Howland KL, Lewis NI, Locke A, Peña A, Poulin M, Rochon A, Rourke WA. Three decades of Canadian marine harmful algal events: Phytoplankton and phycotoxins of concern to human and ecosystem health. *Harmful Algae.* 2021 Feb 1;102:101852.

- Harmful algal blooms occur annually on both the Atlantic and Pacific coasts of Canada, negatively impacting human and marine life. Harmful algae are may be more widespread in Canadian Arctic than previously thought. Evaluating the potential role of harmful algae as stressor on Canadian marine ecosystem is needed.

Rashidi H, Baulch H, Gill A, Bharadwaj L, Bradford L. Monitoring, managing, and communicating risk of harmful algal blooms (HABs) in recreational resources across Canada. *Environmental Health Insights.* 2021 May;15:11786302211014401.

- Scan on provincial and territorial government agency protocols around harmful algal blooms in Canada suggest variations in the monitoring, managing, and communicating of risk to the public. Strategies are explored for better communicating of the risks associated with HABs, creating a coherent system and inter-agency communication is suggested.

<u>Presentations</u> (West Coast)

Esenkulova S, Pawlowicz R, Frederickson N, Pearsall I. Oceanographic conditions and harmful algae in the Strait of Georgia, Canada – outcomes of seven years of monitoring with the citizen science program. Salish Sea Ecosystem Conference 2022.

Ross ARS, Surridge B, Hartmann H, Mueller M, Frederickson N, Esenkulova S, Pearsall I. Profiling marine biotoxins in the Salish Sea. Salish Sea Ecosystem Conference 2022.

Ross ARS, Surridge BD, Mueller M, Haque O, Hewison T, Frederickson N. Relationships between harmful algal biotoxins and environmental conditions in British Columbia coastal waters. Ocean Sciences Meeting 2022, February 24–March 4.

Shartau R. Harmful algal toxins in coastal British Columbia and their effect on salmonids. Department of Fish and Oceans Canada Seminar 2021.

Ross ARS, Surridge BD, Hartmann H, Mueller M, Haque O, Hewison T, Frederickson N, Johnson S, Shartau R, Turcotte L, Locke A, Hennekes M, Nemcek N, Shannon H, Sastri A, Perry IA. Recent advances in measuring and predicting the occurrence and impacts of harmful algal biotoxins in British Columbia coastal waters. PICES-2021 Virtual Annual Meeting, October 25–29.

2.1.2 A new monitoring program

Fisheries and Oceans Canada (DFO) has established a program for monitoring multiple classes of marine biotoxins (including ASP, PSP and DSP toxins) in British Columbia coastal waters, using liquid chromatography-tandem mass spectrometry (LC-MS/MS), based on collaborations with the Pacific Salmon Foundation (PSF) Citizen Science Program and partners in the BC Salmon Aquaculture Industry. The goal of this Marine Biotoxin Monitoring Program is to increase understanding of the dynamics and drivers of harmful algal blooms and associated biotoxins that can impact wild and farmed salmon and endangered marine mammal in British Columbia coastal waters. The program, which has been running since 2020, has revealed seasonal changes in biotoxin levels associated with the timing of marine algal blooms, and significant correlations between water temperature and the concentrations of several biotoxins (including domoic acid, dinophysitoxin-1, pectenotoxin-2, and the PSP toxin C1). This work will be presented during Session S9 of PICES-2022 (Ross *et al*. 2022).

2.1.3 HAB events on the Canadian West Coast in the past year

<u>East coast of Vancouver Island/Salish Sea</u>

During 2021 there were thick vivid orange blooms of *Noctiluca scintillans* (up to 3200 cells per mL) in April, *Heterocapsa triquetra* (up to 9000 cells per mL) in June, *Dictyocha* spp. (up to 150 cells per mL) in July and August, and *Rhizosolenia setigera* (up to 500 cells per mL) and *Pseudo-nitzschia* spp. (up to 1800 cells per mL) in July and August. *Alexandrium* spp. and *Dinophysis* spp. were very abundant, but there were no blooms of *Heterosigma akashiwo* (Esenkulova *et al*., 2022).

During 2022 there were thick blooms of *Noctiluca scintillans* (up to 1000 cells per mL) in May and August, and a mix of diatoms (*Skeletonema*, *Rhizosolenia*, *Thalassiosira*, and *Pseudo-nitzschia* spp.) in August (unpublished observations of the Citizen Science monitoring program, Pacific Salmon Foundation). Sample analysis for 2022 is ongoing.

West coast of Vancouver Island

In late summer 2021 relatively high concentrations of domoic acid (DA) were measured on the west coast of Vancouver Island, using ELISA. On August 26 a DA concentration of 427.5 pg/ml was measured at station P2, off the south-west coast of the Island, while on September 16 a very high concentration of 974.8 pg/ml was measured further north, at station LBP3. For reference, seawater concentrations above 200 pg/ml are generally regarded as a concern in terms of the potential for DA accumulation in shellfish.

2.1.4 Other notes

In summer, 2021, the British Columbia Centre for Disease Control was reported in the media as having diagnosed an infection in a human being by the marine bacterium *Shewanella* sp., which is apparently the first time this has occurred in BC. The man had been wading in Baynes Sound, exposing a partially healed wound to sea water several days after experiencing an injury to his leg, and subsequently developed symptoms of sepsis. Another resident of the same area had apparently been seriously ill several years earlier after washing a wound in the ocean, but the cause of that infection was not investigated. The media report states that *Shewanella* was not previously known to be in British Columbia waters, and speculates as to a ballast water source, but Makemson *et al*. (1997) had previously reported the genus in Saanich Inlet sediments and BC seawater.

2.1.5 References

Comox Valley Record (2021)
https://www.comoxvalleyrecord.com/news/denman-island-man-battles-infection-from-rare-bacteria/

Esenkulova S, Pawlowicz R, Frederickson N, Ross A, Pearsall I (2022). Spring-summer oceanographic conditions and harmful algal blooms in the Strait of Georgia 2021. In Boldt JL, *et al*. (Eds.) (2022) *State of the physical, biological and selected fishery resources of Pacific Canadian marine ecosystems in 2021.* Canadian Technical Report of Fisheries and Aquatic Sciences 3482.
https://publications.gc.ca/collections/collection_2022/mpo-dfo/Fs97-6-3482-eng.pdf

Makemson JC, et al. (1997) *Shewanella woodyi* sp. nov., an exclusively respiratory luminous bacterium isolated from the Alboran Sea. *International Journal of Systematic and Evolutionary Microbiology* 47:
https://doi.org/10.1099/00207713-47-4-1034
https://www.microbiologyresearch.org/content/journal/ijsem/10.1099/00207713-47-4-1034

Ross ARS, Surridge BD, Hartmann H, Mueller M, Hennekes M, Haque O, Frederickson N, Esenkulova S, Johnson S, Turcotte L, Locke A (2022). Correlations between ocean temperature and the concentrations of harmful algal biotoxins measured in British Columbia coastal waters. PICES-2022.

2.2 China (Reported by Douding Lu and Pengbin Wang)

2.2.1 Red tides

According to China Marine Disaster Bulletin, 42 HAB events were recorded in China's coastal waters of the Bohai, Yellow and East China seas in 2021, covering a total area of 17,081 square kilometers. The important HAB organisms in the coastal waters of China, are as follows: *Noctiluca scintillans, Prorocentrum donghaiense, Prorocentrum minimum, Prorocentrum micans, Akashiwo sanguinea. Alexandrium catenella, Heterosigma akashiwo, Phaeocystis globosa, Gonyaulax polygramma, Chaetoceros curvisetus.* Among them, *Noctiluca scintillans* caused the most red tides (14 times).

In terms of regional distribution, the East China Sea has the largest number of red tides and the largest cumulative area, which is 26 times and 7096 square kilometers, respectively. From the distribution of coastal provinces, the number of red tides in Zhejiang was the largest and the cumulative area was also the largest, with 22 times and 7084 square kilometers, respectively. In terms of seasonal pattern, the red tide was found the most frequently in September, at 12 times. February was the month in which the largest cumulative area of red tide was found, with a total area of 6006 square kilometers. The longest single red tide event occurred in the coastal waters of Tianjin, with a duration of 51 days, from September 1 to October 21, and a maximum area of 104 square kilometers.

2.2.2 Green tide

In 2021, the green tide scale in the Yellow Sea reached a historical maximum (Figure 1). On June 26, the distribution area of Yellow Sea green tide was about 60,594 Km^2, covering an area of 1,746 km^2, which was 2.3 times that of 2013, the previous largest year. The area covered by *Ulva prolifera* in 2021 in the Qingdao sea area is 9 times that of 2020. From April to August in 2021, the green tide affected the Yellow Sea area of China, and its distribution area reached a maximum of 61,898 km^2 on June 21. The maximum coverage was reached on June 26 at about 1,746 km^2 (Figure 2). *Ulva prolifera* is the causative species of green tide.

Fig. 1 *Prolifera* green tide in the sea area of Xiaomai Island, Qingdao City.

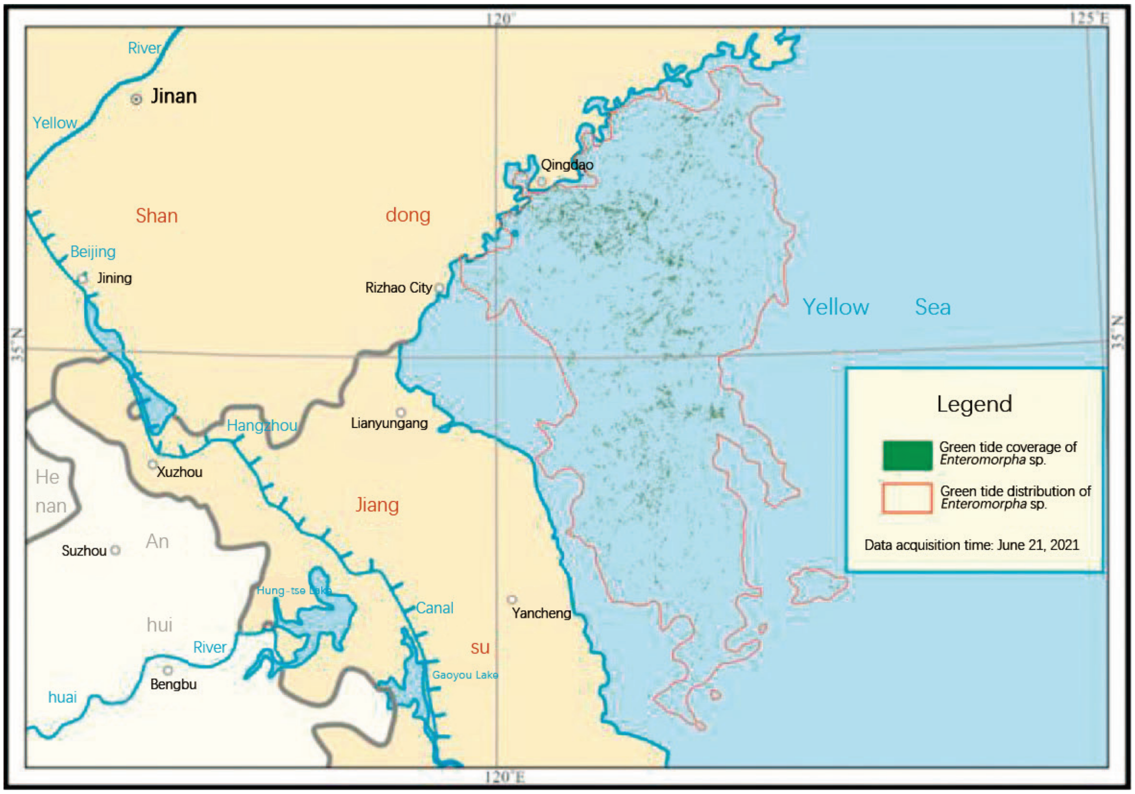

Fig. 2 Distribution pattern of green tide in coastal waters of the Yellow Sea on June 21, 2021.

2.3 Japan (Reported by Natsuko Nakayama, Yoichi Miyake, Setsuko Sakamoto, Mitsunori Iwataki)

We report HABs and their associated fisheries issues in 2021–2022 (up to August 2022).

2.3.1 Long-term and recent trends of HAB events

The inter-annual variation in the blooms and the economic losses caused by HAB events have been reported over the past few decades in western Japan, such as in the Seto Inland Sea and Kyushu area. In the Seto Inland Sea, the number of blooms decreased in the 1970s–1980s and has been slowly declining in the recent decades. In the Kyushu area, the number has been on the rise overall.

2.3.2 HAB events and impacts on the fisheries in 2021

HAB events in Japan mainly take place in its western parts, such as the Seto Inland Sea and Kyushu area. Major HAB species are *Karenia mikimotoi*, *Chattonella* spp., *Cochlodinium polykrikoides*, *Heterocapsa circularisquama*, and *Heterosigma akashiwo*.

In 2021, the numbers of HAB events were 70 and 100 in the Seto Inland Sea and Kyushu area, respectively. In Hiroshima (western Seto Inland Sea), *Chattonella* spp. (maximum density; 1,009 cells/mL) killed 15,420 yellowtail (*Seriola quinqueradiata*) in mariculture, resulting in an economic loss of 26 million JPY. The bloom of *Chattonella* sp. (maximum density; 110,000 cells/mL) occurred in the Yatsushiro Sea (western Kyushu area) and killed 64,600 white trevally (*Pseudocaranx dentex*), causing 91 million JPY of damage.

In 2022, *K. mikimotoi* blooms widely occurred in western Japan. In the Yatsushiro Sea, where *Chattonella* blooms have been predominant in recent years, *K. mikimotoi* blooms have occurred (started in late July and are still ongoing as of August 26th). The blooms of *Chattonella* spp. occurred in both the Seto Inland Sea (July–August) and Kyushu area (July–August).

2.3.3 Shellfish ban by the PSP and DSP

Most of the shellfish closure caused by paralytic shellfish poisoning (PSP) and diarrhetic shellfish poisoning (DSP) occur in the southwest (Seto Inland Sea and Kyushu area) and north Pacific coast (Tohoku area and Hokkaido) of Japan. There were 48 cases of shellfish ban due to PSP in 2021. The number was down by approximately 31%, compared with that of the previous year. Shellfish species subject to the shellfish ban include scallops, sea squirts (wild), and oysters. The causative species of PSP in 2021 were mainly *Alexandrium catenella*, *A. pacificum*, and *Gymnodinium catenatum.* They were mainly observed from March to June, with densities exceeding 10^4 cells/L at some sites. There were 6 cases of shellfish ban due to DSP in 2021, and the number was down by approximately 34%, compared with that of the previous year. Shellfish species subject to the shellfish ban include scallops and blue mussels. The causative species for DSP were *Dinophysis fortii* and *D. acuminata*. They were observed mainly from July to September, with densities exceeding 10^3 cells/L at some sites. While the number of the shellfish bans due to PSP and DSP has decreased compared to those of 2020, they have been on the rise in recent years, and the distribution of the toxic species has also been expanding.

2.3.4 Massive outbreak of *Karenia selliformis* on Pacific coast of eastern Hokkaido, Japan in 2021

An unprecedented large-scale harmful algal bloom occurred on the Pacific coast of eastern Hokkaido, Japan, from September to November 2021. It caused extensive fishery damage due to the deaths of sea urchins, chum salmon, fish juveniles and octopi. The damage exceeded 8 billion JPY, and subsequent research revealed that the dominant species was *Karenia selliformis*. The blooms caused by *K. mikimotoi* have been frequently reported in Japan, but it was the first time that *K. selliformis* had been observed in massive numbers in Japanese waters. The water temperature at which the cell density was high (>100 cells/mL) was in the range of 9.8–17.6 °C (Iwataki *et al*. 2022). Currently, multiple investigations are ongoing to understand the *K. selliformis*, including its growth physiology, and to reveal cause of the large-scale bloom (*e.g*., Kuroda *et al*. 2022).

2.3.5 References

Iwataki M. *et al.* 2022, Morphological variation and phylogeny of *Karenia selliformis* (*Gymnodiniales, Dinophyceae*) in an intensive cold-water algal bloom in eastern Hokkaido, Japan*, Harmful Algae,* 114, 102204. doi.org/10.1016/j.hal.2022.102204

Kuroda H. *et al.* 2022, Distribution of Harmful Algae (*Karenia* spp.) in October 2021 Off Southeast Hokkaido, Japan. *Frontiers in Marine Science 9:841364. doi: 10.3389/fmars.2022.841364*

2.4 Korea (Reported by Moonho Son, Tae-Gyu Park, Minji Lee, Seokhyun Yoon)

2.4.1 Variation in HABs in Korean coastal waters since 1970

Since the beginning of HAB monitoring in 1972, the number of HABs continued to increase from the 1980s to the 1990s. After the largest number of HAB incidents (109) in 1998, the trend declined until the 2010s. Most HABs in the 1970s were caused by diatoms. In the 1980s, coastal dinoflagellates caused HABs; *Cochlodinium polykrikoides* blooms have occurred continuously since 1993. The concentration of nutrients in coastal waters was the highest in the 1980s and has declined since the mid-1990s. This reduction in nutrient concentration is a good explanation for the decreasing number of HABs. Since 2016, a summer high water temperature of 30°C or more has appeared, and the range and scale of *C. polykrikoides* blooms have been greatly reduced.

In 2016, *K. mikimotoi* blooms occurred around Wando, Jangheung, and Goheung and small-scale blooms of *C. polykrikoides* occurred around Yeosu. There were no *C. polykrikoides* blooms in 2017; however, *Alexandrium affine* blooms occurred from Yeosu to Tongyeong. There were small-scale blooms of *C. polykrikoides* in 2018 compared to those in the previous years. Due to the long rainy season in 2020, diatoms and *Ceratium furca* have dominated and the water temperature and salinity was lower than the normal average. So blooms of *C. polykrikoides* in 2018 occurred in mid-October and lasted for a month. Our results show that reduction in nutrients and the high water temperature owing to climate change are good explanations for variation in HABs in Korean coastal waters.

2.4.2 Occurrence of HABs in 2021

Eleven cases of algal blooms were observed in 2021. There was a bloom of the dinoflagellate *Akashiwo sanguinea* once in April and May, the dinoflagellate *Noctiluca scintillans*, once in June and July, the diatom *Skeletonema* sp. once in July, the ciliate *Mesodinium rubrum* once in October and 3 times in November. Algal blooms of *Ceratium furca*, *etc*. were observed a total of 64 times in 2020, but the high biomass of diatoms such as *Chaetoceros* spp. and *Skeletonema* sp. were observed in ocean regions where *Cochlodinium* blooms occurred (Tongyeong ~ Goheung waters) during summer 2021. The *Cochlodinium* bloom in 2021 appeared at 8~320 cells/mL around Jeollanam-do on August 9. However, it has been observed to be less than 1 cell/mL since August 14. The bloom has occurred in a narrow range of less than 1 km. The main factor in the non-growth/spreading of *Cochlodinium* was the creation of an ecological environment unfavorable due to the continued dominance of competing organisms such as diatoms in the waters surrounding the occurrence of the bloom. The unusual increase in the biomass of diatoms in the summer is the rainy season due to the late stagnant front, and frequent rainfall in the southern coastal area is identified as the largest cause.

2.4.3 Appearance of *Alexandrium* species related to PSP in 2021

Paralytic shellfish poisoning (PSP) occurs every year in Korea. Currently, countries around the world are responding sensitively to the problem of shellfish toxins in terms of public health, and are strengthening regulations such as toxin inspection and quarantine for foreign aquatic products imported into their countries. The time of occurrence of PSP is getting faster recently, and in particular, during the outbreak of PSP in 2018, it increased and spread so fast that many fishermen missed the time to collect shellfish and suffered economic losses. In addition, as some shellfish such as mussels in circulation exceeded the paralytic shellfish toxin standard, it became a social problem. Accordingly, in Korea the collection is prohibited, depending on the concentration of shellfish toxin, and prior to this, demand for forecasting shellfish toxin according to the appearance of plankton, the cause of shellfish poisoning,

The main cause species for early (Feb – Apr 2021) PSP in Jinhae Bay was *Alexandrium catenella*, and the PSP that occurred after May was *Alexandrium pacificum*. Plankton related to shellfish toxin showed a high correlation with the concentrations of dissolved inorganic nitrogen (DIN; negative) and dissolved organic nitrogen (DON; positive). A shellfish poison was detected anomalously in January 2021, which was analyzed as a result of the temporary occurrence in shellfish poison plankton due to DIN restriction by low rainfall in winter. It was confirmed that *A. catenellas* prefer low temperatures (5∼20°C) for excystment and growth of vegetative cells. In other words, shellfish poison that occurs under low water temperature in Jinhae Bay is considered to be caused by *A. catenella*. On the contrary, the growth of *A. pacificum* is confirmed to mainly occur in high water temperatures (15∼25℃), and their growth is limited by many factors (slow growth rate of *A. pacificum* and interspecific competition, *etc*.) during this period. Thus, the occurrence of shellfish poison in Jinhae Bay is expected to be related more to *A. catenella* than to *A. pacificum*. The mechanism of large-scale occurrence of shellfish poison in Jinhae Bay is summarized as follows: 1) Absorption of inorganic nitrogen flowed from rainfall by diatoms, 2) Development of low inorganic nitrogen (< 1 μM) and high organic nitrogen (> 12 μM) condition due to absorption and decomposition by diatoms, 3) Massive outbreak of shellfish poison plankton.

2.5 USA (Reported by Misty Peacock, William Cochlan, Mark Wells, Vera Trainer)

2.5.1 Overview

West Coast incidences of HAB events produced mostly domoic acid (DA), and PSTs, though there were often infrequent reports of DSTs, shellfish killing toxins (yessotoxin), and there was some evidence of freshwater cyanotoxins transferred to marine habitats (including Alaska). There were continued incidences of marine mammal strandings in 2021–2022, with a current HAB event in California that is causing many marine mammal strandings. There were periodic commercial fishery closures in four states (California, Oregon, Washington, and Alaska). In California, Oregon, and the Washington outer coast, closures were due to domoic acid routinely (CA and WA outer coast) and PSTs (WA and AK). Continued efforts for more offshore HAB sampling, modeling/forecasting of domoic acid, ocean acidification and multi-stressor events, satellite/remote sensing for HABs, identification of new/emerging HABs, and freshwater toxin transfer to the marine environment are areas of interest for academic, governmental, and tribal harmful algae researchers. Use of Imaging FlowCytobot (IFCB) technology is a key technology and the US west coast network is expanding. Several NOAA ECOHAB and MERHAB projects were funded in 2021 to address HABs on the west coast.

2.5.2 California

California coastal waters are monitored by HABMAP, Coastal Ocean Observing System, and multiple state, federal, academic, private, and tribal partners for harmful algae and toxins. Sampling is still decreased due to COVID-19 lab closures compared to pre-2020. There were punctuated *Pseudo-nitzchia* reportings in Southern-Central California, typically in spring, though it continued into fall 2021.There were marine mammal strandings during the spring in California (few) and currently (August–September 2022) California is in the midst of a large (likely) offshore DA event, which is causing many mammal strandings. *Alexandrium* incidences were infrequent or non-existent in southern California, but were present above 10,000 cells/L in central and northern California, and Northern California was closed due to PST toxins in shellfish in the summer/fall of 2021 and summer of 2022. Razor clam fisheries were closed in northern California from December 2021–June 2022 because of DA. August–September 2022, central and northern CA are closed due to PSTs, and also an unprecedented *Heterosigma* HAB event in San Francisco Bay which is linked to fish kills. Closures due to *Dinophysis* and DSP events were not reported, and *Dinophysis* was infrequent in samples. There were multiple ASP and PSP commercial and recreational harvest closures throughout California, though they were short-lived. California continues to produce a state-wide HAB newsletter (CA HAB Bulletin), weekly updates by email, and use of the C-HARM model for DA forecasting. Central and Southern California have also began including freshwater toxins found in the marine environment in weekly/monthly updates to the harmful algae community. There is a statewide Imaging IFCB System for harmful algae which can be accessed at https://ifcb.caloos.org/dashboard.

2.5.3 Oregon State

Oregon coastal waters are monitored for harmful algae by the ORHAB and SoundToxins monitoring programs, as well as the State of Oregon public health (shellfish). In 2021 from north to south, there are higher cell counts for *Pseudo-nitzschia* (both large and small) and greater concentrations of pDA, with toxic events happening in April–June, and September–November. Throughout 2021, both *Alexandrium* and *Dinophysis* spp. were present periodically at sampled sites. There were commercial and recreational shellfish biotoxin closures for PSP events in November 2021, February and May 2022. There were no reported marine mammal strandings due to biotoxins.

2.5.4 Washington State

Washington State marine waters are monitored for harmful algae by the ORHAB, SoundToxins, Washington Department of Health programs, and tribal nations. There were PSP events in multiple counties of Washington, along the entire coast of Washington State, including the inland Salish Sea. The State analyzed ~2500 shellfish samples for PSP, DSP, and/or ASP. There were multiple commercial and recreational closures, though fewer than in 2020. ASP events are confined to the coast (southern Washington) though *Pseudo-nitzschia* was seen throughout Washington State sampling locations, and into the South Salish Sea (Puget Sound). DSP events were mostly confined to inner Puget Sound though there were no commercial DSP closures. In Northwest Washington there were more than 30 subsistence harvest closures for PSP and/or DSP events in 2021, which is less than in 2020. There are still periodic tribal beaches closed currently in the Northern Washington, mainly to PSP. There was one confirmed hospitalized illness for PSP in Washington State last year. There were fewer shellfish die-offs compared to 2021. Monitoring efforts to identify other yessotoxin shellfish die-off events are currently ongoing, as is the implementation of an IFCB network. There is also current work being done to monitor for DA offshore of Washington coast. DSP and PSP events did not continue into the winter (January and February) in 2021, but there are current blooms of both *Protoceratium reticulatum* and *Alexandrium* spp. in the North Salish Sea that is impacting shellfish harvests. Several NOAA ECOHAB and MERHAB projects to monitor for HABs (using IFCBs, AUVs, ESPs, and more traditional methods) were funded for Washington State, as was support to expand data collection through citizen science, tribal, academic, and state partners.

2.5.5 Alaska

Alaska coastal waters are monitored by Alaska Harmful Algal Bloom network (AHAB), SoundToxins, Southeast Alaska Tribal Ocean Research (SEATOR), Kachemak Bay National Estuarine Research Reserve (KBNERR), Alaska Sea Grant, Aleutian Pribolof Island Association, NOAA, and other tribal, governmental, and academic groups. There continues to be elevated levels of PSTs found in shellfish throughout the year at various southeast Alaska beaches. In southeast Alaska, ~1000 shellfish and ~500 water samples were monitored for *Alexandrium*, and PSTs, including cysts. Near commercial and subsistence geoduck beds an alarming number of *Alexandrium* cysts were present, but there has (of yet) been no correlation between cyst presence and winter geoduck toxicity. Samples from southeast Alaska routinely saw PSTs in salmon kidneys and livers, but not edible meat and eggs. Kodiak, Alaska sampled in 2021 was >80% of the time above the regulatory limit for PSTs at one beach, but less than 10% at the other two beaches, showing the difficulties in providing shellfish safety measures for subsistence harvesters. The Aleutian and Pribilof Islands sampled weekly in 2021, and similar to Kodiak sampling, blue mussel samples were sometimes above the regulatory limit for PSTs, though not with the toxicity levels of 2020. The Bering Sea had clams with elevated PSP levels, and both ASP and PSP were found in stranded or harvested marine mammals' stomachs. There is a new publication (Anderson *et al*. 2022) in *Oceanography* describing some of the HAB incidences in the Alaska arctic from the last few years. Similar to other US west coast states, Alaska has newly funded ECOHAB (NOAA) projects aimed at monitoring for PSTs and domoic acid by mapping cell densities and health assessments from marine mammals. Alaska has the most extensive network of citizen scientists monitoring for (mainly) PSTs, where 100% of coastal Alaskans subsistence harvest. The AHAB network and website presence has been updated substantially in the last year, and facilitates gathering HAB data into one location.

2.6.1 Russia (Reported by Tatiana Orlova, Tatiana Morozova, and Inna Stonik)

In 2021 and 2022 a monitoring survey focusing on potentially toxic species was conducted in Amur Bay off Vladivostok City (Peter the Great Bay, Sea of Japan). Several HAB events, caused by dinophyte, diatom, and raphidophyte algae, were observed (Table 2). In 2021, bloom events caused by these *Pseudo-nitzschia* species were recorded from the surface horizon in Amur Bay four times (5.6×10^5 cells L^{-1} in late August, dominated by *P. pungens*; 8×10^5 cells L^{-1} in early September, dominated by *P. calliantha*; 1.2×10^6 cells L^{-1} in late September, dominated by *P. delicatissima*; and from 5×10^5 cells L^{-1} to 3.4×10^6 cells L^{-1} during early September to early October, dominated by *P. multistriata*) (Fig. 3).

Table 2. List of harmful algal species recorded in Amur Bay, January 2021 to August 2022.

Date	Species	Maximum abundance, cells L^{-1}
Sept.–Oct. 2021	*Alexandrium pseudogonyaulax*	220×10^3
	Pseudo-nitzschia multistriata	3.4 × 106
	Pseudo-nitzschia delicatissima	1×10^6
July–Aug. 2022	*Alexandrium pseudogonyaulax*	102×10^3
	Dinophysis acuminata	3.7×10^6
	Dinophysis forthii	4×10^3
	Noctiluca scintillans	12×10^6
	Prorocentrum minimum	28×10^6
	Prorocentrum triestinum	3.7×10^6
	Scrippsiella sp.	6.2×10^6
	Heterosigma akashiwo	46.3×10^6
	Skeletonema spp. complex	60×10^6

An accumulation of domoic acid was detected in the samples of the bivalves *Modiolus kurilensis* (2 mg kg^{-1}) and *Crenomytilus grayanus* (0.9 mg kg^{-1}) collected in late October 2021 after bloom events caused by *P. multistriata* and *P. delicatissima*. These concentrations of domoic acid were substantially below the regulatory limit of 20 mg kg^{-1}, but, nevertheless, significantly higher than the concentrations (0.1–0.3 mg kg^{-1}) previously reported for bivalve samples from this area (Stonik *et al*., 2019). No cases of ASP were recorded.

In 2022, the summer bloom of phytoplankton in the Amur Bay has become the longest in time (for approximately one and a half months) for the entire 30-year period of microalgae monitoring in Peter the Great Bay. The concentration of the species that caused it has also reached the maximum values for this region. No cases of human poisoning or animal mortality were recorded.

As the results of the monitoring of hydrological characteristics show (Fig. 4), from July 13 to August 9, 2022, the sea surface temperature (SST) increased from 21 to 27.1°C; sea surface salinity (SSS) varied from 0 to 10 ppm; chlorophyll *a* concentration varied from 10 to 64 mg m^{-3}. Along the transect, the average thickness of the layer with chlorophyll *a* concentrations (higher than 2 mg/m^3) increased from 3 to 6 m. The turbidity (concentration of suspended particles in the water) was greater than 60 mg/m^3. Oxygen in the surface layer of water, due to the long-term and intense microalgae bloom, reached 170%, which corresponds to a significant oxygen saturation of water, while low oxygen concentrations (less than 4 mg L^{-1}) indicating hypoxia were recorded from the near-bottom layer of water (up to 5 m thick).

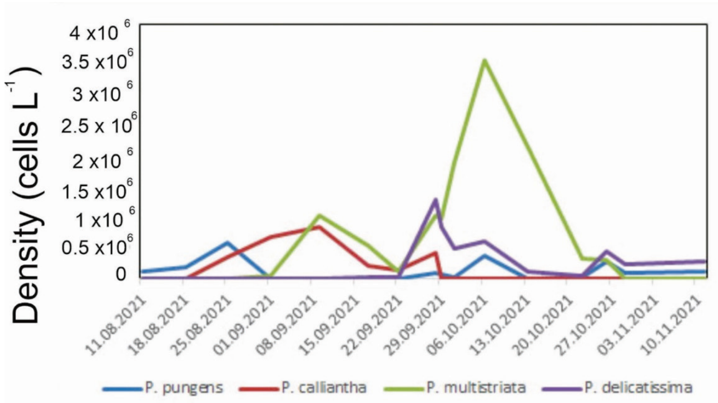

Fig. 3. Cell density of *Pseudo-nitzschia* spp. in the surface horizon at the monitoring station in Amur Bay in the summer and autumn of 2021.

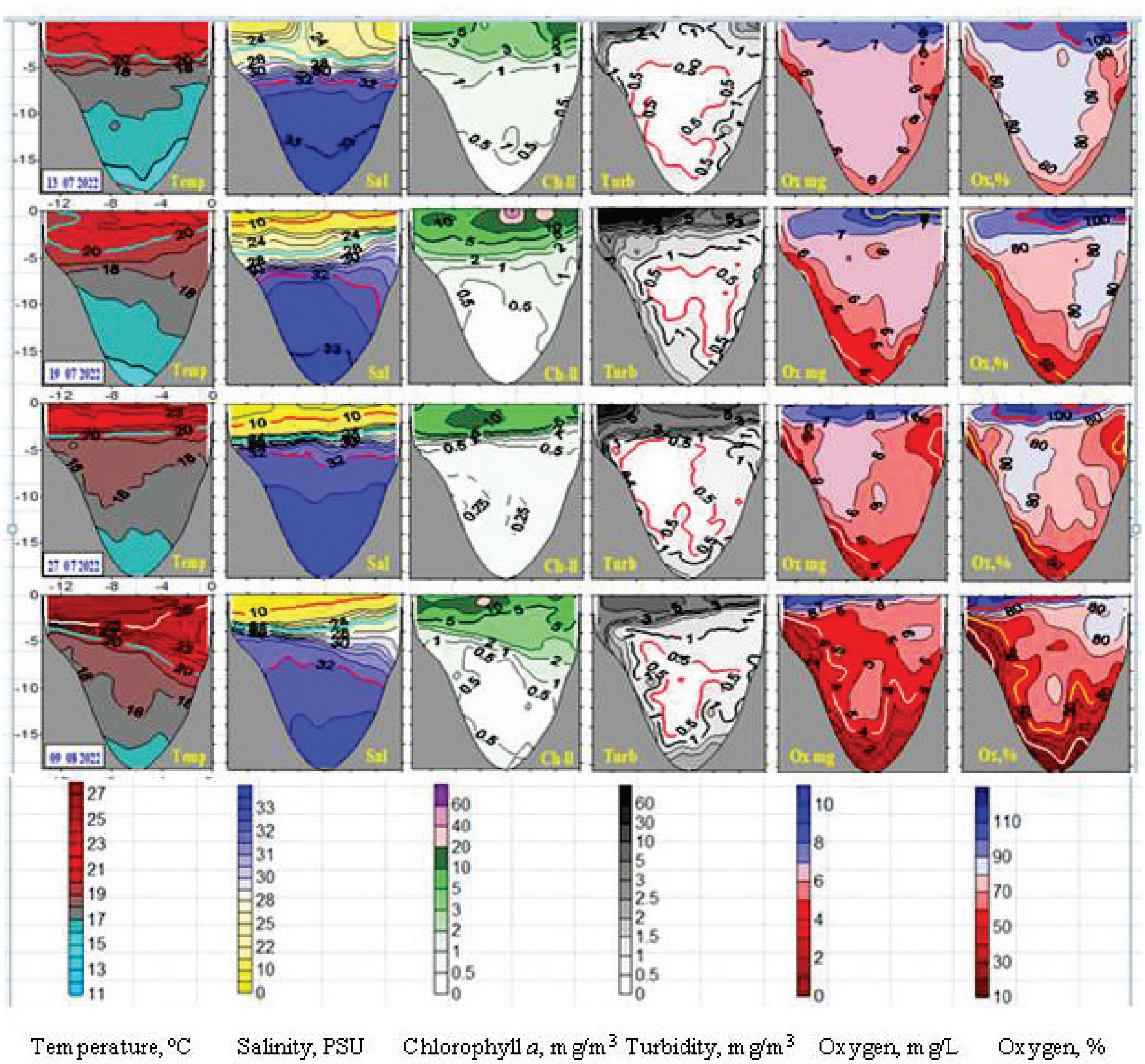

Fig. 4. Results of the monitoring of hydrological characteristics in Amur Bay along the transect line from Cape Krasny to Peschanaya Cove from July 13 to August 9, 2022.

AGENDA ITEM 3
MAFF project

Dr. Wells reported on progress of the PICES project "Building Local Warning Networks for the Detection and Human Dimension of Ciguatera Fish Poisoning in Indonesian Communities" funded by the Ministry of Agriculture, Forestry and Fisheries (MAFF) of Japan through the Fisheries Agency of Japan (JFA), from the Official Development Assistance (ODA) Fund. Ciguatera Fish Poisoning (CFP) in tropical reef fisheries globally has the greatest human health and economic impacts of any algal-based poisoning syndromes. CFP stems from the human consumption of fish containing toxins produced by benthic microalgae of the genus *Gambierdiscus* and *Fukuyoa*, dinoflagellates which are the initial sources of ciguatoxin. Although CFP is recognized to occur in pristine environments, its emergence in new regions, and intensification in others, often is associated with anthropogenic pressures. There also is evidence that climate drivers may affect its distribution. The primary concerns for local communities are first to identify reef regions where the causative organism is abundant and second, to manage their anthropogenic stressors to minimize increases in its presence.

Indonesia has one of the most extensive coral reef systems in the world on which many of its coastal communities depend upon for its biodiversity and ecological products. However, presently only about 7% of these coral reefs are in excellent condition, whilst more than 35% are in poor condition, mainly due to anthropogenic stressors. The methods to measure the presence and abundance of these harmful species are not well developed, and details of the toxin transfer to communities are a challenge to understand both as a biological event and as a social event. This was the rationale for the Ciguatera project.

The onset of the COVID-19 pandemic significantly affected the planned project activities. The Project Science Team worked in close collaboration with Dr. Suhendar I Sachoemar (formally BPPT) and Dr. Arief Rachman (formally LIPI), both now under the reorganized Indonesian National Research and Innovation Agency (BRIN) to adapt to the evolving conditions. A Memorandum of Understanding (MOU) was arranged and signed between PICES and the University of Indonesia Institute of Technology to support the current project and to help sustain activities into the future. Work on the smartphone App FishGIS, developed in the previous MAFF (Building capacity for coastal monitoring by local small-scale fishers; FishGIS) project and expanded for use here, continued through this Year 3 of the project. The project augmented a BRIN-funded field sampling project designed for water quality and toxic benthic dinoflagellate observations in the Gili Islands, Indonesia. Data collected on these field programs are being incorporated into the FishGIS generated database, and will help to inform Gili Island communities on the ecological health of their local waters. With the pandemic concerns easing, the long-awaited training workshops will begin in January 2023 on the Lombok and Gili Island region.

AGENDA ITEM 4
Workshop proposal for PICES-2023

A proposal draft was circulated prior to the meeting for an International Workshop on "*Solutions to control HABs in marine and estuarine waters*" at the next PICES Annual Meeting (*S-HAB Endnote 3*). The initial plan was to hold this workshop at the 20th International Conference on Harmful Algae in Hiroshima, Japan (2023). The decision was made that the 2023 PICES Annual Meeting would be a more effective platform to increase participation. With input and discussion, the draft proposal was modified and there was unanimous agreement to submit the proposal to MEQ.

AGENDA ITEM 5
Topic Session Proposal for PICES-2023

A Topic Session proposal draft was circulated before the meeting entitled "*The oceanographic, ecological and societal impacts arising from extreme weather and climatic events in coastal regions*" (*S-HAB Endnote 4*). The goal is to gain a better understanding of past extreme events, and the nature of associated ecological and socio-economic stress. After discussion the topic session proposal participants were unanimous in moving that the proposal be submitted to MEQ for consideration.

AGENDA ITEM 6
Requests to MEQ

- Workshop Proposal: Workshop on Solutions to Control HABs in Marine and Estuarine Waters;
- Topic Session Proposal: The Oceanographic, Ecological and Societal Impacts Arising from Extreme Weather and Climatic Events in Coastal Regions;
- Travel support for 1 invited senior scientist and 1 invited Early Career Scientist for the workshop on Solutions to Control HABS ($5000);
- Travel support for one invited speaker to the topic session on Extreme Events ($2500);
- Full-day S-HAB meeting at PICES-2023;
- Travel support for 1 PICES representative to attend the IOC Intergovernmental Panel on Harmful Algal Blooms (IPHAB) in 2023 ($3,000);
- Request that a replacement be named for Dr. Andrea Locke (Canada), who has retired.

S-HAB Endnote 1

S-HAB participation list

Members

Pengbin Wang (China, Co-Chair)
Mark L. Wells (USA, Co-Chair)
Charles Trick (Canada)
Chunlei Gao (China)
Chunjiang Guan (China)
Douding Lu (China)
Yoichi Miyake (Japan)
Mitsunori Iwataki (Japan)
Setsuko Sakamoto (Japan)
Moonho Son (Korea)
Seung Ho Baek (Korea)
Tatiana V. Morozova (Russia)
William Cochlan (USA)
Misty Peacock (USA)
Vera L. Trainer (USA)
Takafumi Yoshida (*ex officio*, representing NOWPAP)

Members unable to attend

Canada: Andrea Locke, Andrew RS Ross
China: Hao Guo, Qiufen Li, Mengmeng Tong
Japan: Natsuko Nakayama
Korea: Hae Jin Jeong, Kwuang Young Kim, Tae Gyu Park
Russia: Mikhail Simokon, Tatiana Yu. Orlova

Observers

Ruoyu Guo (China)
Minji Lee (Korea)

S-HAB Endnote 2

S-HAB meeting agenda

1. Welcome and introduction
2. HAB Country Reports
3. MAFF project
4. Workshop proposal for PICES-2023
5. Topic Session proposal for PICES-2023

S-HAB Endnote 3

Proposal for an International Workshop on
"*Solutions to control HABs in marine and estuarine waters*"
at PICES-2023

Convenors: Vera Trainer (USA), Quay Dortch (USA), Marc Suddleson, (USA), Zhiming Yu, (China), Tae-Gyu Park, (Korea), Natsuko Nakayama, (Japan), Don Anderson, (USA), Mark Wells (USA), Pengbin Wang (China),

Potential Co-sponsors: GlobalHAB, ICES, NOAA, (possibly get UNDOS endorsement)

Duration: 1.5 day

Harmful algal blooms (HABs) are a ubiquitous problem that affect marine and estuarine waters around the world. Advances in our understanding of bloom dynamics, improved HAB detection, and increased monitoring in many regions have enabled explorations of promising approaches to prevent and mitigate coastal blooms at multiple geographical scales. However, only a few approaches are available and therefore effective and scalable marine and estuarine HAB control remains an elusive goal for many global regions. For example, spraying of clay from ships has been used as a physical mechanism to control active *Margalefidinium* (*Cochlodinium*) blooms in Korea, as well as *Phaeocystis*, *Aureococcus* and other HAB species in China, and the use of naturally-occurring bacteria or their exudates is being explored as a chemical method to control raphidophyte blooms and some dinoflagellates. Some other examples of control include the use of oxidizing agents such as peroxide, percarbonate, ozone, and UV irradiation, as well as direct biomass removal, water column mixing, native seagrass or macroalgal planting, barley straw application, direct application of algaecides. The societal desire to have access to a greater variety of safe and effective bloom control options has become more urgent given the continued development of coastal regions for aquaculture, tourism, and other uses that are impacted by HABs. An international workshop to explore approaches to HAB control in marine and estuarine waters will stimulate an international dialogue, foster in situ experimentation, and support assessments of social, economic and environmental costs and benefits of various approaches. A discussion of different strategies for navigating environmental compliance will highlight the processes used in different countries to overcome the complexities of rules and regulations and may highlight ways that national regulatory policies could be adjusted to quicken the pace of developing safe and effective HAB control approaches. The workshop will specifically focus on HAB control mechanisms, and not prevention or mitigation. The following definitions are provided for clarification. Control efforts focus on the organisms themselves, either killing them or removing cells and/or toxins from the water. An example is the use of clay spray to control fish-killing HABs. Prevention approaches focus on stopping blooms from occurring or minimizing and limiting their extent. An example is reducing nutrient inputs to water bodies to reduce HAB growth. Mitigation focuses on relieving the impacts of blooms without direct action on HAB cells and their toxins. An example of mitigation is the use of phytoplankton monitoring to provide early warning of HABs.

Early warning allows multiple actions to minimize the impacts, such as closure of shellfish harvesting before they become too toxic for human consumption. The international workshop will engage participants with expertise in research, development, and implementation of promising estuarine and marine HAB control approaches. We encourage the participation of early career ocean professionals and scientists from under-represented communities. Participants will discuss technical, environmental compliance and public perception challenges and explore solutions to these common barriers. In depth discussions of existing control methods and strategies used in different regions/countries will be fostered. The workshop findings will summarize the worldwide approaches in HAB control as a scientific report or as a collection of papers in a special issue of *Harmful Algae*.

S-HAB Endnote 4

Proposal for a Topic Session on
"*The oceanographic, ecological and societal impacts arising from extreme weather and climatic events in coastal regions*"
at PICES-2023

Convenors: Pengbin Wang (China), Moonho Son (Korea), Charles Trick (Canada), Misty Peacock (USA), William P. Cochlan (USA)

Potential Co-sponsors: GlobalHAB, IOC UNESCO, ICES WGHABD, ISSHA (potential), NOWPAP

Duration: 1 day

Climate drivers have and continue to strongly influence the physical and biogeochemical properties of ocean surface waters, and these effects become magnified during extreme events. Coastal regions are particularly sensitive to extreme events. In addition to being affected by the onshore movement of anomalous oceanic water, coastal regions are subject to rapid fluctuations in precipitation-driven runoff as well as mixing associated with nearshore wind patterns. The increasing occurrence of extreme change in nearshore waters can intensely influence nutrient supply, dramatically altering ocean ecology in ways that can cause extensive socioeconomic stress. The outcomes of these integrated processes vary widely given the complexity of drivers, magnitudes and dynamics of change, making it difficult to proactively identify problems in time to take steps towards mitigation. Nevertheless, better understanding of past extreme events, and the nature of associated ecological and socioeconomic impacts, will provide the foundation for developing prediction and response strategies. This topic session will help to inform the Working Group 49: Climate Extremes and Coastal Impacts in the Pacific by helping to develop a census of historical climate extreme events around the Pacific Rim to describe their characteristics, identify potential climate and ocean drivers, and catalog the ecological and socioeconomic consequences (ToR#1). The session also addresses the UN Decade of Ocean Science for Sustainable Development goal towards developing a common framework for improving conditions for sustainable development of the Ocean. We welcome papers that address the oceanographic, ecological, and socioeconomic outcomes associated with extreme events in coastal oceans and particularly encourage papers that seek linkages among two or more of these aspects that help to illustrate the underpinnings of ecological and socioeconomic responses to extreme events.